March 2004

Sampling to Estimate Current Levels of Asbestos in Apartments in the EPA Clean-Up Area Near the World Trade Center Site

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INTRODUCTION

In the period following the destruction of the World Trade Center towers, EPA together with the City of New York and other participating agencies, worked to address contamination of residences by dust from the collapse. In particular, a program was established to provide air sampling and apartment cleaning to residents living near the Trade Center, and residents of approximately 4200 apartments requested and received cleaning and/or sampling.

In a letter to Senators Clinton and Leiberman, dated 10/27/03, James Connaughton, Chairman of the Council for Environmental Quality, advised that EPA would convene a panel to address specific issues associated with past and ongoing impacts from the collapse of the World Trade Center towers. The first of these issues is to review, *"Post cleaning verification sampling to be done by EPA in the residential areas included in EPA's Indoor Air Cleanup to verify that re-contamination has not occurred from central heating and air conditioning systems"*. This document outlines a proposal which is intended to meet this sampling objective using a rigorous statistical sampling design. The intended audience for this proposal is the Expert Technical Review Panel that will be meeting for the first time on March 31, 2004.

This proposal is comprised of two parts. The first part is an overview of the proposed survey design, and the second is the statistical sampling design itself developed under contract by Westat, Inc. In the first part, sections include an introduction, the statistical sampling proposal, and a description of post-survey data analyses. This part was drafted by an EPA working group comprised of representatives from the Office of Research and Development's National Center for Environmental Assessment including Henry Kahn, Matthew Lorber, and Paul White, and from the Region 2 office including Pat Evangelista, Mark Maddaloni, Chuck Nace, Dennis Santella, and Stanley Stephansen, with the assistance of William Thayer from Syracuse Research Corporation. The second part on the statistical sampling design was developed under EPA contract by Graham Kalton, David Ferraro, and Lou Rizzo of Westat, Inc, and their design document is titled "Sample Design Options for the Survey of Apartments Participating in the World Trade Center Residential Cleanup Program". Westat is known widely as a research contractor with expert corporate qualifications in survey research, study design and statistical analysis. Dr. Graham Kalton is a senior vice president of Westat and one of the leading survey statisticians in the world. Dr. Kalton is known for his published research on survey methodology and leadership in the design and implementation of many large scale surveys. Dr. Kalton served as president of the International Association of Survey Statisticians, was formerly the Chairman of the Biostatistics Department at the University of Michigan and has authored or co-authored ten books on design of surveys and statistical analysis.

BACKGROUND

The collapse of the towers resulted in the incursion of contaminants to the indoor environment, including residences, business offices, stores, and other commercial areas near Ground Zero. In the "clean-up area" (an area of about 1 mile wide by 1 mile long below Canal St) in Manhattan, it is estimated that there are about 2,000 buildings, of which 500-600 are residential structures. There are approximately 23,000 apartments in these buildings. The EPA apartment clean-up program that followed was a voluntary program. The program cleaned and/or tested 4167 apartments; 3386 apartments were both cleaned and then tested after being cleaned, denoted "cleaned and tested", and 781 were "tested only". This "test" involved agitation to resuspend any asbestos that may have been on the floor or on other surfaces, and then taking an asbestos air sample. The measurement was compared to a health based benchmark level developed for this program of 0.0009 f/cc [see below and "World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health Benchmarks", May, 2003]. Multiple air samples (3 minimum) were collected in each apartment. A measurement above the benchmark value is referred to as an "exceedance". An apartment was deemed "cleared" if all asbestos measurements taken in the apartment were at or below the benchmark. If any sample in an apartment showed an exceedance, or if high dust loading on a filter or other any other factor interfered with the analyses, the apartment was not "cleared" and EPA offered to clean or re-clean the apartment. A total of about 22,000 air samples were collected and tested for asbestos in these 4167 apartments. Forty-four apartments, or about 1% of the total, had at least one asbestos measurement above the health benchmark of 0.0009 f/cc; and 91 or about 2.2% were not cleared because of overloading on the filters.

In order to address the charge from the CEQ letter, certain key issues require attention and will be addressed in the following sections. Specifically, there must be an understanding of the meaning and implications of the term, "re-contamination", and how the survey design will generate data to support the assessment of re-contamination. The design must also address the effect of central heating and air conditioning systems on the assessment of re-contamination.

Issue 1: How will re-contamination be addressed?

The objective for this survey is prompted by concern about re-contamination of apartments by WTC related contaminants. **Within the context of a statistical survey, we are addressing concerns about re-contamination by monitoring for the presence of current asbestos contamination among the large group of approximately 4200 apartments that had been previously addressed in the EPA cleaning and sampling program.** As noted above, there are approximately 23,000 apartments in the clean-up area. There is, however, no

information about the full population's "contamination" status at the time of the Clean-Up Program, so estimating the rate of "re-contamination" of this universe of apartments is not possible. Information on the "contamination" status of the 4167 apartments in the Clean-Up Program is available -- cleaning and followup monitoring was offered to residents of these apartments to achieve "clearance". Thus we judge that a study of re-contamination is most appropriately based on sampling in this population of apartments.

For purposes of the survey, we are using the same definition of "contamination" as was adopted in the previous EPA work: An apartment is contaminated if at least one asbestos test conducted in the apartment measures a concentration above the health-based benchmark established by the EPA program of 0.0009 f/cc. Using this definition of contamination, the status of apartments can be compared between the prior testing and the testing to be conducted under this survey. In general, it should be possible to say that based on the results of the second survey the estimated rate of contamination is less than, greater than or about the same as found in the original survey (recognizing that most of these apartments had been recently cleaned and that judged to be contaminated were offered re-cleaning).

Issue 2: How will the role of central heating and air conditioning be addressed?

The objective from CEQ focuses on central heating, ventilation, and air conditioning (HVAC) systems as a potential source of re-contamination. HVAC systems have the potential to cause re-suspension and circulation of dust; leading to the concern that they might continue to transport WTC related asbestos contamination within buildings. Additionally, in situations where HVACs were not cleaned (or not fully cleaned) during the Clean-Up Program residual contamination within the systems may potentially be spread in a building.

In conducting this survey, EPA will seek to classify and stratify the population of apartments with regard to their HVAC status. This will support a sampling design that allows for estimation of contamination levels in sub-populations of apartments defined by their HVAC status. We stress that while it will be important to examine subpopulations of apartments in buildings according to the presence of HVAC systems, a survey of this kind cannot directly determine the cause of contamination that may be found. The potential for alternate sources of asbestos, which may not be related HVAC systems, or to the collapse of the WTC, would need to be considered in interpretation of any survey findings of elevated asbestos levels.

The EPA Clean-Up Program generated information regarding HVAC systems, although there are not records on the presence or type of HVAC systems for the all apartments that were cleaned and tested. The current survey will include additional steps to characterize HVAC status of tested apartments. For the purposes of study design and stratification, the status of all

apartments with regard to central HVAC systems was determined based on available information. The following are definitions of central HVAC status as well as the number of apartments within these definitions:

1) Apartments in buildings served by central HVACs: These are apartments in buildings with central HVAC systems that serve common areas as well as have some measure of shared air between apartments. It was ascertained that there were 472 apartments (of 4167) in this category in 10 buildings. However, about 430 of these apartments were in one building, 45 Wall St, with the remaining 40 or so spread out in 9 other buildings. For purposes of further discussions, this subpopulation will be termed, "central HVAC".
2) Apartments in buildings with only common areas served by central HVACs: These are apartments in buildings which do not directly share air with other apartments or common areas, and the only air exchange is the venting of air (from bathrooms and kitchens) to the outside of the building. The common areas in many of these buildings are served by central HVACs, but individual apartments are served by individual heat pumps (mostly). There are 2396 apartments in this category. For purposes of further discussions, this sub-population will be termed, "partial central HVAC".
3) Apartments in buildings known not to have central HVACs: This is the smallest category of apartments, containing only 24 apartments. Apartments are served by individual units.
4) Apartments in buildings where HVAC status is unknown: There are 1275 apartments in this category.

In addition to apartments that were in the Clean-Up Program, the Region also conducted cleaning for common areas of some of the buildings containing these apartments. The Region was asked to evaluate HVAC systems in 116 buildings. Of these 116 buildings, 33 were found to have HVAC systems with "visible" contamination. There are 942 apartments that EPA cleaned and then tested in the 28 buildings with "impacted" and "cleaned" HVAC systems (an "impacted" HVAC system was one in which there was visible evidence of the incursion of WTC dust). There are 105 apartments that EPA cleaned and tested in the 5 buildings with "impacted" HVAC systems where the building management declined EPA cleaning. These HVACs were not in all cases central systems. The exceedance of the asbestos benchmark was only 0.5% in buildings with "impacted" HVAC systems, lower than the 1.0% found in the full population of apartments. Perhaps residual contamination exists in the apartments in buildings other than those with "impacted" HVAC systems, that was not removed by cleaning.

These discussions led to the recommendation that all 4167 apartments of the original

sampling program be eligible for selection in this re-sampling effort. **However, as discussed shortly, it is also recommended that information about apartments in the first two categories above, central HVAC and partial central HVAC apartments, be considered a "domain of interest" for the statistical design.**

Issue 3: How will airborne asbestos fibers be sampled and characterized?

Since the "contamination" status of the 4167 apartments was determined using measured asbestos levels, the re-sampling program plans to assess contamination levels using the same analytical protocol used in the previous study. Asbestos fibers will be characterized using PCME counting procedures (Phase Contrast Microscope Equivalent measured by Transmission Electron Microscopy (TEM) - International Standard Organization Method 10312) as followed in the clean-up program. This approach, which counts fibers greater than 5 μm in length, was utilized to allow comparison with existing heath risk assessment data on asbestos, including the cancer characterization contained in EPA's IRIS database. Data on total asbestos fibers, including shorter fibers, will also be collected for consideration as needed.

The Clean-Up Program used two methods of air sampling. Most apartments (3,893) were sampling using a procedure in which a fan is used to circulate air and suspend particles that are then drawn into a sampling device (this procedure is termed "modified aggressive" sampling). A smaller number of apartments (274) were tested with an "aggressive" sampling procedure in which a high speed blower (i.e., a "leaf blower") in addition to a fan is used to agitate and suspend particles in the air in the apartment. This latter procedure has been used in verification sampling for asbestos removal programs, but, is not generally useable in occupied residences. The data in Table 1 indicate that the sampling method does make a difference in the amount of asbestos measured. That is, the rate of "Exceedance" in the "Modified Aggressive" and "Aggressive" groups are 0.72% and 5.8%, respectively. This seems reasonable as the more aggressive method of sampling would result in more asbestos fibers being suspended in air and drawn into the sampling device.

In the re-sampling survey, we have decided to use only the "modified aggressive" method of air sampling. The basis of this decision is that the "aggressive" method does not represent conditions applicable to residential living over the 30 year exposure period used in our risk calculations. Furthermore, the "Aggressive" method of sampling is very disruptive and it is very unlikely that residents would agree to have their apartments sampled using this method.

Table 1. Summary of Test Results in the 4,167 Clean-Up Apartments			
Test Result	Sampling Method		Total
	Modified Aggressive	Aggressive	
At or below benchmark	3780	252	4032
Exceedance (greater than benchmark)	28	16	44
Overload or other sampling problem	85	6	91
Total	3,893	274	4,167

STATISTICAL SAMPLING PROTOCOL

This section will briefly describe the approach for developing alternative designs for sampling of the apartments near that WTC site included in the Cleanup Program. Details of the sampling designs and the methodology used to develop the designs are described in the attached Westat report titled "Sample Design Options for the Survey of Apartments Participating in the World Trade Center Residential Cleanup Program."

Based on discussions above, the following are recommended as statements of objectives for the current resampling effort:

- **To estimate the current asbestos exceedance rate for the 4,167 apartments that participated in the World Trade Center Residential Cleanup Program; and**

- **To estimate the current asbestos exceedance rate for the subset apartments where there may be a potential for re-contamination from shared air systems.**

(1) Definition of sampling "domains"

A "domain" is a subpopulation of individual units within a population that are clearly defined and for which sample estimates are required and precision needs to be quantified. For this survey sample size and sample design need to be able to produce estimates of adequate precision for the two population domains associated with the two primary objectives listed above. The first domain is the entire population of 4,167 apartments and the second includes all apartments classified as "central HVAC" and "partial central HVAC" (as described above). For discussion purposes, this second domain will be called, "central + partial central HVAC". There are a total of 2868 apartments in this second domain. It may have been of interest to produce separate estimates for apartments with central HVAC systems and those with other kinds of

shared air. However, only 472 apartments in the Cleanup Program are known to have central HVAC systems and 430 of them are in a single building (45 Wall Street); the other 42 are in only 9 other buildings. The small number of apartments with central HVAC systems, combined with their concentration in a few buildings, led to the decision that these apartments should not be treated as a separate domain for the survey.

The two key decisions to be made in this study are the overall sample size and the sample size allocated to the domain of apartments with shared air. These decisions will be influenced by of the levels of precision obtained for estimates of the exceedance rates for the two domains. **The sampling protocol examines four overall survey sample sizes of 250, 500, 750, and 1000 apartments.** The results of selected precision calculations are presented below to illustrate how alternatives for the decisions are evaluated. More details are provided in the Westat report.

Sample size decisions should also be influenced by the resources available to conduct the survey and a judgment about whether the cost of achieving greater precision is justified. **However, at current stage, this sampling document it does not address cost or other level-of-effort factors.**

(2) "Stratification" of the apartments for sampling.

Strata are subsets of individual units within a population to be sampled that are clearly defined and distinct. Strata are used to facilitate the design and implementation of a sampling study, but precision estimates for individual strata are not primary study objectives. The sample design for the apartment survey is basically simple. A single-stage stratified sample of apartments will be drawn from the population of 4,167 apartments in the Cleanup Program. .

First, consider the stratification factors that will be employed. These stratification factors are derived from the data collected in the initial testing. The following are brief descriptions of the stratification variables for the entire population of 4167 apartments. All of these stratification variables have been identified in previous discussions:

1) <u>"Clean and test", or "test only"</u>: There were 3386 apartments that were cleaned first and then tested, and 781 apartments that were tested only.
2) <u>HVAC status:</u> The four strata relating to current available data on HVAC status are central HVAC, partial central HVAC, no central HVAC, and unknown. It was decided that the sum of all four comprise the primary domain of "all apartments" and the sum of the apartments in the first two strata comprise the second domain of interest. After conduct of the study, apartments in the "unknown" category will be reclassified using the additional data that is collected.
3) <u>Aggressive and modified aggressive sampling techniques:</u> As noted above it was decided that the sampling procedure will use the modified aggressive method. Apartments that were

previously sampled using the aggressive method will be included in the study domains, and results will be included in the estimation of exceedance rates. However, due to the differences in methods, results for these apartments from the original clean-up program will not be compared to results from the current survey.

4) Apartments with an asbestos detection: While the focus in above discussions has been on measurements that exceed the health standard, it was possible to have a measured asbestos level that was below the health standard. Specifically, a count of 1 fiber on examined area of a sample filter, according to the analytical method used, was equivalent to an estimated concentration of about 0.0004 f/cc, whereas a count of 2 or more fibers in the sample would be essentially greater than the health standard of 0.0009 f/cc. If a measurement resulted in no observed fibers in the sample, it was designated as "non-detect".

5) Apartments with an exceedance of the asbestos health standard of 0.0009 f/cc: There are 44 of these apartments, including 28 (of 3893) from apartments that were sampled using a modified aggressive approach and the remaining 16 (of 274) from apartments that were sampled aggressively.

6) Apartments with an "overload" on the filter. An overload occurs when the filter contains so much particulate matter that a reliable asbestos measurement cannot be made. There were 91 of these apartments, including 85 from apartments with modified aggressive sampling and 6 from apartments with aggressive sampling.

Tables 2 and 3 show how the population of 4167 apartments are distributed among these strata. Table 2 is developed over the entire domain of 4167 apartments and Table 3 shows the distribution for the second domain of interest, the central + partial central HVAC domain. Of particular interest for both these domains are the apartments with exceedances and the apartments with overloads. During the EPA clean-up program, if either of these conditions occurred, apartment owners were offered a free re-cleaning and retesting. It could be speculated that these apartments could have been the most impacted to start with and therefore are of most interest with regard to the question of "re-contamination". **For this reason, it is strongly recommended that all of the 44 apartments showing an exceedance in the previous study be included in this survey, irrespective of the overall sample size for the survey. Further, it is recommended that all 91 apartments with overloads also all be included in the survey.** It should be noted that it is unlikely that data will be obtained from all apartments selected to participate in the survey because it is expected that not all apartment owners will consent to have their apartments tested . For planning purposes, the assumption has been made that there will be

Table 2. Domain 1: Counts of all 4,167 Apartments by clean/test status			
Description	Sampling Method		Total
	Modified Aggressive	Aggressive	
I. Clean and Test			
Non-detect	2870	201	3071
Detect	194	20	214
Exceed the health benchmark of 0.0009 f/cc	20	15	35
Overload	62	4	66
Totals	3146	240	3386
II. Test Only			
Non-detect	677	31	708
Detect	39	0	39
Exceed the health benchmark of 0.0009 f/cc	8	1	9
Overload	23	2	25
Totals	747	34	781
Overall Totals	3893	274	4167

a response rate of 60 percent, meaning that it is expected that only 60% of the apartment owners will consent to participate in the survey.

For the purpose of drawing a sample, strata for apartments sampled with certainty (e. g., the exceedance and overload apartments) are removed from the list from which the sample will be drawn. A constant sampling fraction will then be used within each of the remaining strata. A sampling fraction is simply a fraction of apartments sampled from within the strata; a 0.10 sampling fraction for a population of 100 is 10. The use of a constant sampling fraction yields what is termed proportionate stratification. Proportionate stratification has the attractive feature that it can only improve the precision of survey estimates as compared with an unstratified design. It cannot cause a loss of precision.

Table 3. Domain 2: Counts of 2,868 Apartments with Central HVAC or Partial Central HVAC by clean/test status			
Description	Sampling Method		Total
	Modified Aggressive	Aggressive	
I. Clean and Test			
Non-detect	2011	183	2194
Detect	135	15	150
Exceed the health benchmark of 0.0009 f/cc	15	10	26
Overload	38	4	42
Totals	2199	212	2412
II. Test Only			
Non-detect	394	29	423
Detect	21	0	21
Exceed the health benchmark of 0.0009 f/cc	2	1	3
Overload	9	1	10
Totals	426	31	457
Overall Totals	2625	243	2869

(3) Use of "oversampling"

Without information about current exceedance rates for the different strata, a proportionate allocation of the sample across the primary strata would also be appropriate for estimating the overall exceedance rate under the first objective listed earlier. However, a proportionate allocation may yield a smaller sample of apartments with shared air systems and yield an estimate of the exceedance rate of lesser precision for the second domain. Thus a disproportionate allocation, or 'oversampling', of apartments with shared air systems may be advantageous. For a fixed sample size, this oversampling of the second domain will result in less precision for the overall estimate than would have been achieved with a proportionate allocation.

(4) Estimates of statistical precision

As an aid to making decisions about the total sample size, and what proportion of the total sample size to allocate to the shared air domain, we examine four rates of oversampling for the shared air domain: no oversampling—i.e., a proportionate allocation and an oversampling ratio of 1.0—and sampling the shared air domain at 1.5, 2.0 and 2.5 times the rate used for the apartments with no shared air (the sum of no shared air and unknown). The sample sizes that result from the 16 combinations of these two factors are displayed in Table 4. As the table shows, for a given overall sample size, an increase in the oversampling rate for the shared air domain reduces the sample size for apartments with no shared air. As a result, the estimate of the exceedance rate for the apartments with no shared air becomes less precise, which in turn lowers the precision of the estimate of the exceedance rate for the total population of apartments in the Cleanup Program.

To illustrate the magnitude of the sampling errors resulting from the above 16 sample designs, we computed approximate standard errors (i.e., standard deviations) for the sample estimate of an exceedance rate of 1 percent (see Appendix B of the Westat report for details.) These computations assume that the proportionate stratification does not reduce the standard error to an appreciable extent. The resultant standard errors may therefore be overestimates, but the extent of overestimation is likely to be negligible. Table 5 presents the standard errors for the total domain estimate (T) and the shared air domain (S) for each of the 16 sample designs. Note that with an oversampling rate of 2.5, the standard errors for the estimated exceedance rates for the total domain and for the shared air domain are about the same.

Table 4. Sample sizes for various combinations of total sample size and the oversampling rate for the shared air domain (S) as compared with the rate for apartments with no shared air (NS)

Oversampling rates for shared air domains	250		500		750		1,000	
	S	NS	S	NS	S	NS	S	NS
1.0	170	80	339	161	509	241	679	321
1.5	190	60	380	120	570	180	760	240
2.0	202	48	404	96	606	144	809	191
2.5	210	40	420	80	631	119	841	159

Table 5. Standard errors, in percent, for an estimated exceedance rate of 1 percent for the total population (T) and the shared air domain (S) for the 16 sample designs								
Oversampling rates for shared air domains	250		500		750		1,000	
	T	S	T	S	T	S	T	S
1.0	0.61	0.74	0.42	0.51	0.33	0.40	0.27	0.33
1.5	0.62	0.70	0.43	0.48	0.34	0.37	0.28	0.31
2.0	0.64	0.67	0.44	0.46	0.35	0.36	0.29	0.30
2.5	0.67	0.66	0.46	0.45	0.37	0.35	0.31	0.29

Table 5 shows how the sampling error decreases with increasing sample size. Also, for a given total sample size, the sampling error of the estimate for the shared air domain decreases with higher rates of oversampling; however, the sampling error of the estimate for the total population increases, but only slightly, with higher rates of oversampling. The sample design to be chosen should be the one that satisfies the precision requirements for both domain estimates with the smallest sample size.

The interpretation of the standard error involves considering the variation in the sample estimates that would occur if the same sampling procedure were repeated an infinite number of times. The standard error is then the square root of the average of the squared deviations of the sample estimates from the true population value. With large samples, approximately 95 percent of the sample values will fall in the interval P - 1.96SE to P + 1.96SE, where P is the population value and SE is the standard error. Although this approximation is not entirely adequate when both P and the sample size are small, it can nevertheless provide useful guidance.

Suppose, for example, that the true exceedance rate is 1 percent in a population of 4,200 (rounded for simplicity), i.e., 42 of the apartments are in exceedance. Consider a sample of 1,000 apartments with no oversampling (i.e., an oversampling rate of 1.0). Then, from Table 5, the standard error for the sample proportion in the total domain is SE = 0.27. Thus, if we hypothetically assume that the full survey sampling was repeated multiple times, approximately 95 percent of the exceedance estimates from the repeated sampling would fall in the interval from 1.0 - (1.96 x 0.27) to 1.0 + (1.96 x 0.27) or from 0.47 to 1.53 percent. We can also express this in terms of numbers of apartments with exceedances - the 95% confidence interval for the number of apartments observed to be in Exceedance would be 4.7 to 15.3; this corresponds to a 95% confidence interval estimate of 20 and 64.

Consider now the same design but with a sample of 500. The standard error from Table 5 is now 0.42. In this case, the interval within which 95 percent of the sample estimates would fall is widened to from 0.18 to 1.82 percent and the corresponding interval for the estimated number of the 4,200 apartments in exceedance would be from 7 to 77. Thus, by effectively doubling the cost of the survey (i.e., from 500 to 1000 samples), the precision of the estimate as measured by the size of the confidence interval is changes from (7, 77) to (20, 64).

In practice, of course, only one sample is selected, and the issue becomes one of placing a range around the sample estimate within which the true value lies, termed a "confidence interval." Computation of confidence intervals in the case of small proportions requires special techniques. Appendix B of the Westat report describes a method for computing approximate confidence intervals for this case. Table 6 provides an illustration of a more detailed table contained in that Appendix. This table illustrates the statistical results for the potential case where the survey would find 1% of sampled apartments in exceedance of the criteria. Note that Table 6, as well as the following Table 7, use a more accurate statistical methodology for calculation of confidence intervals based on the hypergeometric distribution. The technical approach is explained in the Westat report.

The first row of Table 6 indicates that if three of the apartments out of a sample of 250 apartments, sampled without oversampling, are in exceedance, the estimate of the exceedance rate is 1.20% percent. The 95 percent confidence interval for the true exceedance rate from this small sample is a wide one, from 0.27% to 3.40%. The widths of the confidence intervals decrease (and precision increases) as the sample size increases.

Table 6. Illustrations of approximate confidence intervals for given sample sizes and numbers of sampled apartments in exceedance, for the case of sampling without oversampling.

Sample Size	Number in exceedance	Estimate	95% confidence interval	
			Lower bound	Upper bound
250	3	1.20%	0.27%	3.40%
500	5	1.00	0.34	2.24
750	8	1.07	0.42	1.82
1,000	10	1.00	0.53	1.74

The above discussion has focused on the estimation of the exceedance rate and computing a confidence interval for it. This will be one of the main results of the survey. In order to settle on a final survey sample size, the following tables were developed which incorporate more of the statistical variables and results discussed to this point that are important to final decisions on sample size and apartment selection for the survey: These variables are: 1) oversampling rate - Table 6 above only showed the case of sampling without oversampling; the oversampling rate was 1.0. The next tables show the effect of selecting an oversampling rate of 2.0, meaning that the key domain of shared air apartments will be oversampled by a factor of 2.0 as compared to non-shared air apartments, 2) numbers of apartments found in exceedance of the health standard. Table 6 above only showed the case of finding about 1.0% in exceedance. The following tables will show the exceedance rate found in the sampling survey of about 3.0%; and 3) 95% confidence interval for the full population of 4,167. Table 6 only showed the confidence interval for the full survey population of 4,167. The next tables also show the confidence intervals that are derived for the domain defined by shared HVAC status.

Tables 7 provides another illustration of the results of the sampling precision estimates addressing in this case a situation where it is assumed that a 3% exceedance rate is seen in the study results. It is now incumbent upon EPA, with the assistance of the Panel, to determine the combination of sample size and oversampling rate to be used in the upcoming survey.

Table 7. Illustration for full population domain of 4,167 apartments, assuming an oversampling rate of 1.0, and a finding of about 3.0% in exceedance

Sample Size	Number in exceedance in full population	Estimate	95% confidence interval	
			Lower bound	Upper bound
250	7	2.80%	1.18%	5.61%
500	15	3.00	1.75	4.77
750	22	2.93	1.94	4.28
1,000	30	3.00	2.15	4.11

(5) Addressing non-response.

A general concern in statistical surveys is that not all individuals selected will in fact be reachable and agree to participate. This survey requires sampling in homes and may be disruptive of individuals schedules, thus not all participants from previous EPA cleanup effort are expected to be interested in a retest at this point in time. As non-response can limit the validity of survey estimates, strenuous efforts will therefore be made facilitate and encourage participation. As one incentive, residents will be offered the opportunity to have their apartments cleaned if they are found to be in exceedance.

In order to maintain the intended sample size, substitute apartments will be surveyed as replacements for non-responding apartments. Each substitute apartment will be carefully selected to be similar to its non-responding apartment. Substitute apartments will be selected from the same substratum as the non-responding apartment, and to the extent possible as the adjacent apartment in the ordered list in that substratum. This matching of substitute and non-responding apartments aims to reduce the bias in the survey estimates that can arise from non-response. The use of substitution does not replace the need to make every effort to collect data from the original sample.

Substitution is not applicable in the case of the groups in which all the apartments are selected for the survey. For planning purposes, a response rate of 60 percent has been assumed for these groups. The sample losses from non-response in these groups will be allocated to the rest of the sample in order to maintain sample size. Non-response weighting adjustments will be used in the analyses in order that these groups are not under-represented.

(6) Difficulty of conducting "background" sampling

An important survey design consideration for surveys of this nature is "background". Ideally, a reasonably large number of apartments in upper Manhattan and possibly nearby boroughs might be sampled as a comparison to the apartments that will be sampled now in the Clean-Up area in order to provide a measure of "background" levels of asbestos in apartments not in the Clean-up area. **It is proposed that this resampling effort not include background sampling** for these reasons: 1) a large number of apartments would need to be included in such a "background" sample, likely greater than 300 in order for the results to have an acceptable precision, and this would take resources away from the sampling of apartments in the Clean-Up area, 2) practically speaking, EPA encountered enlistment problems (identifying willing apartment owners) when conducting a small background study during 2002, and an effort now would likely result in similar problems which, at the very least, would require substantial additional time before sampling and analysis results could be generated.

(7) Additional buildings warranting sampling

There were a series of apartments cleaned by Region 2 as well as the city of New York in buildings on Liberty St that were heavily impacted by the collapse of the World Trade Center Towers. These include apartments in the buildings at 110 Liberty (the location of the Confirmation Cleaning Study; 13 apartments), 114 Liberty (cleaned by the City of New York using methods similar to those used by EPA in the Clean-Up Program; 13 apartments), and 125 Liberty (also cleaned by NYC; 25 apartments). These were cleaned using similar procedures as are proposed here. **Because of the importance of these apartments, it was proposed that they be sampled at a rate of 100%.** Given the response rate of about 60%, this will add about 51 apartments to the final study design. The analysis of the results from these sampling will be separate from the full statistical results from the primary study apartments.

POST-SURVEY DATA INTERPRETATION

The primary objective of the sample design was to determine a sample design that would support the estimation of the current rate of contamination in the full population of apartments (4,167 apartments) originally sampled in 2002-2003 as well as in a domain of interest, central + partial central HVAC (2,868 apartments), with an acceptable level of precision. Once the survey results are available, EPA will be in a position to construct estimates of rates of contamination and conduct analyses which can further examine differences between the two populations. The overall objective is to use estimates of current rates of contamination to address questions of "re-contamination". This section provides a general outline of the analyses planned.

(1) Population-based analyses

"Contamination" was earlier defined as a concentration of asbestos fibers that exceeded the health benchmark of 0.0009 f/cc. The health benchmark is defined in terms of long fibers which are fibers greater than five microns (5 μm) in length. Given the volume of air taken into the samplers specified by the analytical protocol, the 0.0009 f/cc standard is equivalent to a fiber count in the sample of 2 or more. A count of 1 fiber is equivalent to a concentration of about half this at 0.0004 f/cc. In the original survey, there were "detections"(i.e., measurements) of asbestos below the health based benchmark but greater than zero in 253 apartments, or about 6% of the total. In addition to counts of long fibers, the original survey as well as the new survey will count "short fibers", or fibers in the length range of 0.5 to 5.0 μm. Therefore, comparative population-based analyses include: 1) rate of non-detect of short and long fibers, 2) rate of detection of short and long fibers, 3) concentration ranges for short and long fibers, and 4) rate of contamination.

(2) Apartment-by-apartment paired testing

As discussed in the introduction, the notion of "re-contamination" requires an assumption that at one time apartments were contaminated, then were cleaned and/or "cleared" by the EPA cleaning program, and then have become "re-contaminated". Given this interpretation, perhaps the question of "re-contamination" can best be answered by examining the apartment-specific results from apartments that were at first determined to be "contaminated" or likely to be "contaminated". EPA has judged that these most likely "originally contaminated" apartments are: 1) the ones which were found to contain asbestos at measurements at or above the health-based benchmark (44 apartments), 2) the ones which were found to contain an "overload" result (91 apartments), and 3) apartments outside the Region 2 Clean-Up program but were known to be impacted and underwent a rigorous cleaning using methods identical or similar to the methods used in the Clean-Up Program. These include apartments in the buildings at 110 Liberty, 114 Liberty, and 125 Liberty. Like the exceedances and overloads, it is proposed that the apartments at these locations be sampled at a rate of 100%. Given an expected response rate of 60%, a total of 104 apartments in the full set of re-sampled apartments may be the most informative regarding the possibility of "re-contamination". Paired testing for other apartments may also be informative - if a substantial number of apartments originally "cleared" are now estimated to be "contaminated", this may be an indication of "re-contamination".

(3) Comparison to Background

Instead of a conducting a new background sampling effort, EPA will review the available literature on ambient asbestos levels and seek other sources of data (e.g., unpublished data) in order to provide a perspective on background with which to study compare results.

The EPA Background Study itself, which was conducted between March and June of 2002, generated data on asbestos and provided a comparison with the data from the original EPA clean-up program during 2002 and 2003. This background study was conducted in upper Manhattan and collected a total of 62 samples in 25 apartments and 14 apartment building common areas. None of the background samples exceeded the health benchmark of 0.0009 f/cc, although 3 samples (5%) had detectable asbestos.

Other sources of information are not as directly comparable because of the likelihood of using different methods, as well as the possibility of using different censoring methods (treatment of non-detects) if comparing mean concentrations. The Toxicological Profile for Asbestos developed by the Agency for Toxic Substances and Disease Registry (ATSDR, 2001) did contain summaries of studies which measured for asbestos in the indoor environment. For example, one study reported average concentrations of airborne asbestos fibers > 5 μm in length of 0.00008 TEM f/cc and 0.00022 TEM f/cc in 43 non-school buildings and 73 school buildings,

respectively. (Reference: ATSDR (2001). Toxicological Profile for Asbestos. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Atlanta, Georgia..) More detailed results from studies such as these might provide useful comparisons to data collected in the Clean-Up Program because TEM methods were used and asbestos fibers greater than 5 μm were counted.

Generally, efforts will be made to put the results in context not only with results from the first study but with measurements from background settings.